the Building Performance Workshop

PROOF IS POSSIBLE:

How to keep an eye on your new home construction or home improvement

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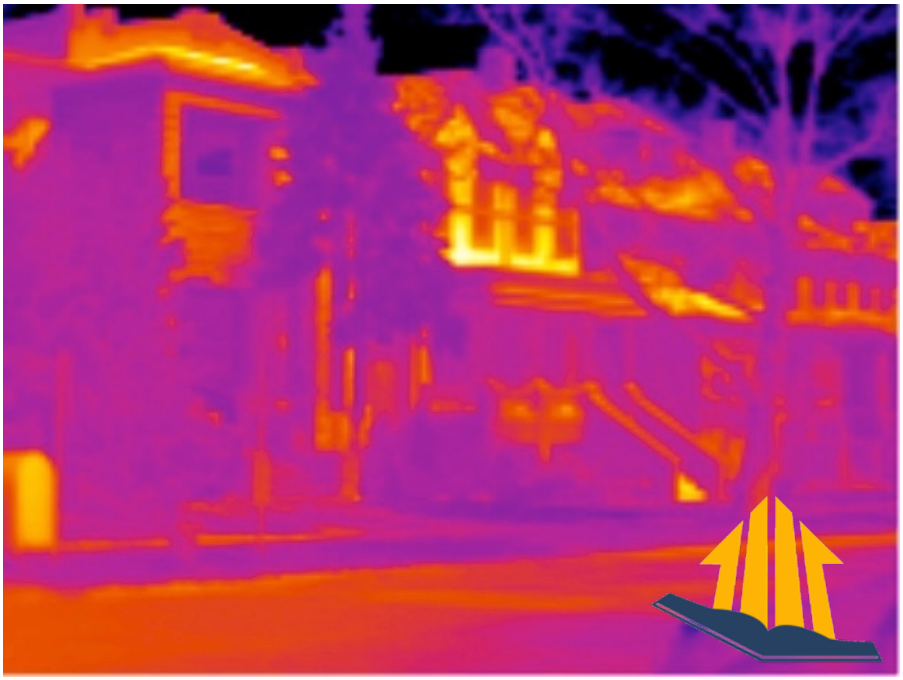
and the *Home Diagnosis* TV Series

DIAGRAM YOUR HOME'S FLOORPLAN:

What are your home's vitals?

Have you had your home's leakage, pressure & temperature tested?

Before you spend hard-earned money on surgery for your home, it should have a physical exam first.



If you've ever **felt lost** while prioritizing home upgrades, or **wasted $1000's** on improvements that didn't perform as promised, or bought a **brand new home** that acted like it was old...

Help is here.

Just like your body or your car, **your home is a system** of interacting and interdependent parts, which goes ENTIRELY against what you may have been trained to think.

If you've ever found yourself with a problem at home (too dry, too wet, too icy, too stale, etc) and went to the store to buy a product off the shelf that you thought would 'fix the problem', that's the obsolete training kicking in.

The reality is that no one product fixes your home as a system, and any symptom you find might actually be an indication of a problem somewhere else in your home.

NOTHING CAN HIDE IN THE 21ST CENTURY

Great news! There are trained home performance professionals across the world who now have the ability to scientifically pinpoint the exact opportunities for improvement in your home so you **never flush another dollar down the drain.**

AND they can prove that the work was done correctly, so you **never worry about getting fleeced.**

Let's be real: owning and maintaining a home can be an expensive and frustrating experience. Anything you can do to make your family more comfortable, healthy and happy at home is awesome. Anything you can do to make your home more valuable and durable is awesome.

AWESOMENESS = PROOF OF QUALITY

When you shop for a car, I bet you want one that's not going to bleed your wallet dry with repairs, gas guzzling and breakdowns. I'm a happily married man, so I know very well that if the family car breaks down in the rain, my bride is going to be unhappy, which makes me unhappy. Happy wife, happy life.

You've invested at least 10 times more in your home than in your car, so shouldn't we all be demanding a guarantee of workmanship in our homes?

This is the promise of home performance:

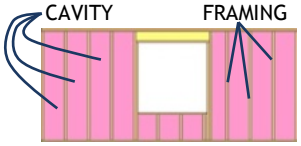
A GUARANTEE OF CONTROLLED COMFORT, GREAT AIR QUALITY, DURABILITY, LOW MAINTENANCE, & ENERGY EFFICIENCY

ELEMENTS		SIGNS	TEST WITH	CONTROL WITH
HEAT FLOW (LOSSES / GAINS)	CONVECTION	DRAFTS	TESTING FANS	AIR SEALING
	CONDUCTION	DISCOMFORT	INFRARED CAMERA	INSULATION
	RADIATION	CONDENSATION	THERMOMETER	
		HIGH ENERGY BILLS	LOW-E DETECTOR	RADIANT BARRIER, LOW-E GLASS
AIRFLOW & PRESSURE (EXFILTRATION / INFILTRATION)	STACK	DRAFTS	TESTING FANS	AIR SEALING
	HVAC	DISCOMFORT	MANOMETER	DUCT SEALING
	WEATHER	TEMPERATURE VARIATIONS	ANEMOMETER	BALANCING
		PRESSURE IMBALANCES	PRESSURE PAN	FANS
MOISTURE	CONDENSATION	DETERIORATION	SURFACE METER	AIR SEALING
VAPOR	DIFFUSION	DISCOLORATION	MATERIAL METER	INSULATION
LIQUID	DRAINAGE	HIGH HUMIDITY	HYGROMETER	PROPER DRAINAGE
	CAPILLARY	ODORS	INFRARED CAMERA	PROPER FLASHING
		INSECTS/SPIDERS		CAPILLARY BREAKS
AIR QUALITY	FUNGUS	RESPIRATORY ISSUES	PARTICLE METER	POLLUTANT REDUCTION
ORGANIC	BYPRODUCT	NAUSEA/HEADACHES	COMBUSTION PROBE	AIR SEALING
PARTICLE	CHEMICAL	ODORS	SNIFFER	INSULATION
	COMBUSTION	MOLD/MILDEW	RADON/MOLD TEST	MECHANICAL VENTILATION
VAPOR	SOIL GAS	CO ALARM	LEAD/ASBESTOS TEST	

There are 4 elements of Home Performance

#4: HEAT FLOW

If you've ever thought your home would be more comfortable with new windows or more insulation, you're definitely not alone, though neither of those is a one-and-done solution. Check this out (don't memorize it, I just want you to know there *is* math that insulation professionals use):



$$U_{Total} = \frac{\left(U_{cavity} \times Area_{cavity}\right) + \left(U_{framing} \times Area_{framing}\right)}{Area_{Total}}$$

What that calculation means is that the difference between a 100% perfect insulation job and a 99% perfect one is a total disaster- a 30% drop in the overall insulation effectiveness. 'Not bad' jobs won't cut it. Be willing to expect and pay for 100% perfect.

#3: AIR FLOW AND PRESSURE

If you've ever had a door slam shut when the air conditioner turns on, or felt a draft of outside air inside your home, then you've seen this element at work. Very few construction professionals understand this one at all. There are 3 drivers of air leakage and pressure imbalances in your home at this very moment:

- Stack Effect (warm air rises and cool air sinks)
- Forced Air Systems (furnaces/air conditioners pushing and pulling air)
- Wind

#2: MOISTURE

As you can see, these elements are *increasing* in importance- that's because the last two elements are the most important on the list. Moisture can tear your house apart quicker than most other things, and it can be bad for your family, too. At this point, we've left energy efficiency in the dust, and we're talking about health and safety.

#1** MOST IMPORTANT ELEMENT: **AIR QUALITY

If your family isn't breathing healthy air, nothing else matters. You would be stunned by how often we find air quality issues from crawlspaces or combustion appliances. Fresh air ventilation should be planned into homes that are reasonably airtight.

Most of the important parts of your home have been covered up.

You deserve to know what's hidden.

There are 3 Opportunities for Improvement

#1 Opportunity: AIR SEALING
Cheap, fast, one-time fix that draws no energy. And if it's not done, neither of the other two will work.

#2 Opportunity: INSULATION
Cheap, fast, one-time fix that draws no energy. Defeated by air leakage.

#3 Opportunity: MECHANICAL SYSTEM UPGRADES
Heating, cooling, and ventilation. Expensive, laborious, energy intensive fix requiring maintenance and replacement. Defeated by air leakage and insulation deficiencies.

Notice that renewable energy systems are not on my list at all. If the three items above aren't taken care of, you'll have to install a big, bloated 'green energy' system that will be impossible to pay off.

There are 2 Home Systems

#1: THE ENCLOSURE (air sealing & insulation)
This is the jacket around your home- the air sealing and insulation layer. If it's uneven or full of holes, it obviously won't be comfortable to live in.

Often, the enclosure isn't where it appears to be. For example, an attached garage or ventilated crawlspace should always be outside the enclosure, but we often find that's just not the case when put to the test, since air leakage always defeats the insulation layer.

#2: THE ENGINE (HVAC- heating & cooling)
Anything that moves heat or air around makes up this system, and it can only work properly when the enclosure works, and the two are 'tuned' together.

Along with windows, HVAC is the most expensive part of your home, so it's a big deal when things aren't working properly. Especially when it might endanger your family, as in a fuel-burning appliance.

There is 1 Goal of Home Performance

The goal is *CONTROL*.

When you have full control over the heat flow, air flow, pressures, moisture, and air quality of your home, then your home is high performance.

Congratulations on your Olympian athlete of a home, when you finally get there! You'll also stop throwing money away on energy waste, decay, and tos of avoidable maintenance.

The only way to prove you have control is Performance Testing

When you get a BEFORE and AFTER comparison of your home's improvement process, you not only get bragging rights at neighborhood get-togethers; you get peace of mind.

Measured performance-based contracting is a business model used by contractors far & wide, so finding the pros who know how to get proven results should be simple now that you know what to ask for. **Proof is Possible.** Ask for it.

The Secret to getting what you pay for in HVAC:

All **Systems** Carefully **Designed**

All **Components** Carefully **Selected**

The Final Installation **Tested** and **Proven** to Perform as Planned

NEXT: Understanding Heating & Cooling

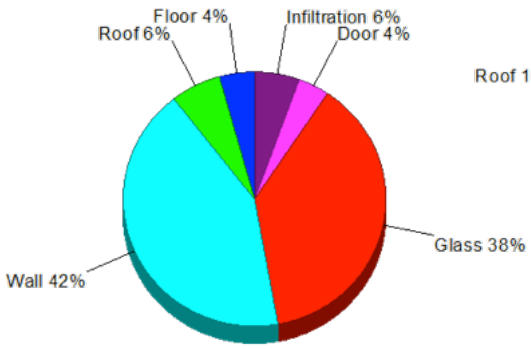
The question is: how much heating or cooling should I install in my home to make it comfortable and cost-effective? Great question! To illustrate:

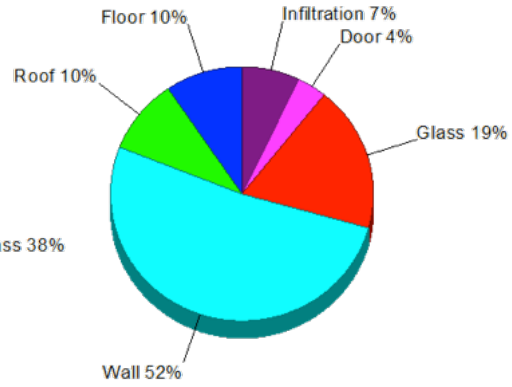
Imagine installing Arnold Schwarzenegger in your house to give your kids access to the cookie jar on the shelf: "One cookie per day is your allowance," you say.

Arnold lifts your children up much too fast and much too high- "NO, put me down!" your children cry as their heads bump the ceiling. Then he drops them much too fast, and they ask to be lifted to the cookie jar again, and the cycle repeats. Pretty soon you have throw-up on the kitchen floor even though zero cookies have actually been eaten.

This analogy is strange and disgusting, but it ***is*** 100% accurate. Your house only needs a **specific amount** of heating and cooling, and equipment that's tailored to fit your home perfectly. If you install too much, the equipment starts up and shuts off a lot- it's called '**Short Cycling'**, and the result in hot weather is indoor air that's cold and clammy, and in all seasons you get worn-down equipment.

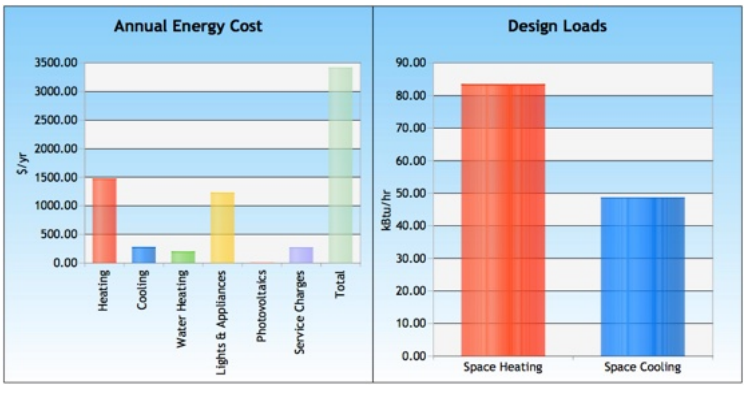
There are very precise design calculations for this spelled out in *ASHRAE Fundamentals* and in *Manual J* from the Air Conditioning Contractors of America. You take detailed data about **weaknesses in the home's enclosure** (called the **'load'**) and put it into a computer.





Doing an HVAC load calculation by hand isn't good enough in most homes because you need an **hour-by-hour analysis** of the sun's effect on the home. This calculation gives you a very specific amount of heating and cooling that a home needs on the **design day**, which is 99% as cold and hot as it gets in your neighborhood. Avoid 'block load' calcs- you should know the requirements of **each unique room**, since they're all different.

You don't need to add any safety margins, because the calculations were written by engineers, who are very cautious and conservative people- **they've added all the safety margins already** to make sure you'll be comfortable.



Next question: how are we going to deliver the warm or cool air evenly everywhere in my home? Wow, what a great question! Guess what? There's a calculation for that too!

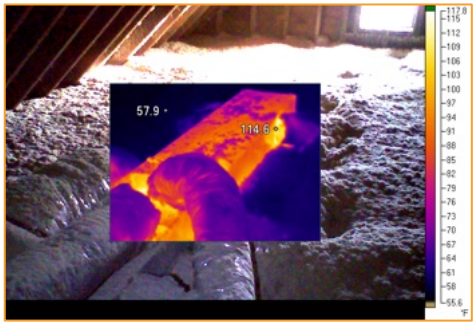
Again, *ASHRAE Fundamentals* or *Manual D* will tell you exactly how the ducts should be designed and installed so that every single room feels comfortable and refreshing, which is possible in every climate, for every home, new and old alike. If you'd rather skip this part entirely, you could choose a **ductless mini-split system**, which has the ability to deliver conditioned air without ducts, and with almost limitless room-to-room zoning control… BUT you will still need ductwork to achieve at least some of the 5 Factors of Ventilation coming up next. There's never a silver bullet solution in the Science of Homes.

Now that we know exactly how much heating and cooling your home needs, we have to buy an engine that can create it. **Here's where most people make a big mistake:** they buy an engine that's too big.

These people may think that they need a little extra power for when the weather is really crazy. Don't do this. Remember a few paragraphs ago, with the cookies and the throw up? That's about to be you.

Last step: we test the **tightness of the duct system**. A duct system is plumbing for air; you **do not** want it leaking. You might think if the ducts are all inside the enclosure and they leak air here or there, it's not such a big deal. It IS a big deal, and here's why:

If we spend time and energy calculating exactly how much heating and cooling each room needs, exactly how the duct system needs to be designed and installed, and pick out the perfect heat pump or furnace...



...all of that gets flushed down the toilet if the conditioned air doesn't actually go to the rooms where you need it.

Last question: what about fresh air? Isn't that a thing? Yes it is, and you get extra credit for asking!

There's a myth that you don't want a home to be 'too tight'. That's nonsense- you want as much control as possible over your home's air leakage. Build tight, **and ventilate right**. The people who say their home is 'too tight' really mean that they forgot to control their chemistry and microbiology by designing and installing home ventilation, which is not rocket science either, and is addressed on the next pages.

If you're going to spend money, time, and energy on your home, make sure it will give you back what you put into it. **Proof Is Possible**, and careful planning and performance testing are the keys. Your home won't need rescuing if you do it right the first time.

Old-timey "Rule Of Thumb":
1 Ton of A/C per ***500*** *ft²*

Actual New Home Estimation:
1 Ton of A/C per ***1000-3000*** *ft²*

RULES OF THUMB DON'T WORK

LAST: Understanding the 5 Factors of Ventilation

To control your home's chemistry and microbiology, which are HUGELY important, we just need to follow 3 basic rules:

1. **Don't bring bad stuff inside**
2. **Keep it dry**
3. **Ventilate**

That first rule is a bit of a joke, since technically speaking WE are bad stuff. Humans off-gas ammonia, formaldehyde, CO2, etc, plus about a pound of skin flakes per year. Gross.

You can follow the Six Classes guidelines to avoid buying products with toxic chemicals built in, but at some point you'll need to be OK with a certain amount of contaminants in your living space, and focus on rules #2 and #3, which will improve your family's exposure to #1. Here's how you can do that:

1: Circulation

Keeping a home both comfortable and healthy requires that the air is mixed around, within rooms and between rooms. Central duct systems were invented for this, but in homes with very airtight and insulated enclosures there's just less air moving through them, so ceiling fans are an easy way to ensure mixing when the HVAC isn't blowing hard enough.

2: Capture and Filtration

CAPTURE: There are places in every home where pollutants are created- mainly kitchens and bathrooms. We can simply grab this polluted air at the source and pitch it outside. Every home needs a kitchen exhaust hood (no matter what kind of cooktop or type of food), and bathroom exhaust. We need either intermittent OR continuous exhaust flow:

- 50 cfm bathroom/100 cfm kitchen minimum exhaust, turned on as needed (intermittent)
- 20 cfm bathroom exhaust 24/7 (continuous)

FILTRATION: The easiest and least expensive way to clean the air is by sifting the contaminants out. Use caution though- the higher the MERV rating, the more particles you capture from the air AND the harder it is on the fan moving the air. Invest in a wider filter for best results- a pleated 4" filter has about 9x the surface area of a 1" filter that's flat.

- MERV 11: 65% removal of big particles, 0% removal of small ones
- MERV 13: 85% removal of big particles, 25% removal of small ones
- MERV 16: 95% removal of big particles, 95% removal of small ones
- MERV 17-20 (HEPA): 99.97% removal of all particles

3: Humidity Control

Too much moisture is a problem, just as too little moisture can be as well. You generally can't depend on your A/C to dry the air in all weather, so dedicated machines for dehumidifying is almost always a good idea (think of it as an insurance policy). Once you build tight enough to need dilution air (#4 below), the home will get noticeably wetter and dryer between summer and winter. *As you move to each new factor of ventilation, always go back and consider how it will interact with the previous factors (eg, how the humidifier is filtered and circulated throughout the home).*

Contaminants come in three types:

Particles

Can cause respiratory or cardiovascular health problems (all particles are bad to breathe)

Chemicals

- From Inside
- From Outside
- Created by Chemical Reaction

(odors and things most people can't smell too- some are 'good' and some are 'bad')

Microbes

There are, and always will be, millions of tiny organisms living on you and in you, and all over your home. Cultivate a healthy home microbiome, just as we do with our guts.

4: Dilution Air

All homes that are well-airsealed, and even some that aren't, need 'fresh air' brought in from outdoors by a fan- because just 'opening a window' will break all three of the 3 Basic Rules of controlling your home's health (above). Calculating precisely how much 'fresh'air from outdoors any home needs is somewhat complex, but is simplified below from ASHRAE standard 62.2:

Table 4-1a (I-P) Ventilation Air Requirements, cfm

	Bedrooms				
Floor Area, ft^2	1	2	3	4	5
<500	30	38	45	53	60
501 to 1000	45	53	60	68	75
1001 to 1500	60	68	75	83	90
1501 to 2000	75	83	90	98	105
2001 to 2500	90	98	105	113	120
2501 to 3000	105	113	120	128	135
3001 to 3500	120	128	135	143	150
3501 to 4000	135	143	150	158	165
4001 to 4500	150	158	165	173	180
4501 to 5000	165	173	180	188	195

5: Pressure Relief

Once a home is reasonably airtight, any fans that pull or push on it have a much greater pressure effect. One-way exhaust fans in the kitchen, bathrooms, and even the clothes dryer can cause problems like combustion backdrafting, chimney odors, moisture, and mold growth. For every CFM of air sent out through the home, an equal amount can be intentionally brought back in through a known pathway, either passively or actively:

- a mechanical damper opens a hole in the wall (passive- always leaves the home slightly depressurized)
- a fan activates to replace the exact CFM required (active- perfect equalization possible)

4 P's of Indoor Pollution Problems

If there is a true Pollution Problem indoors, it's because there are four P's present:

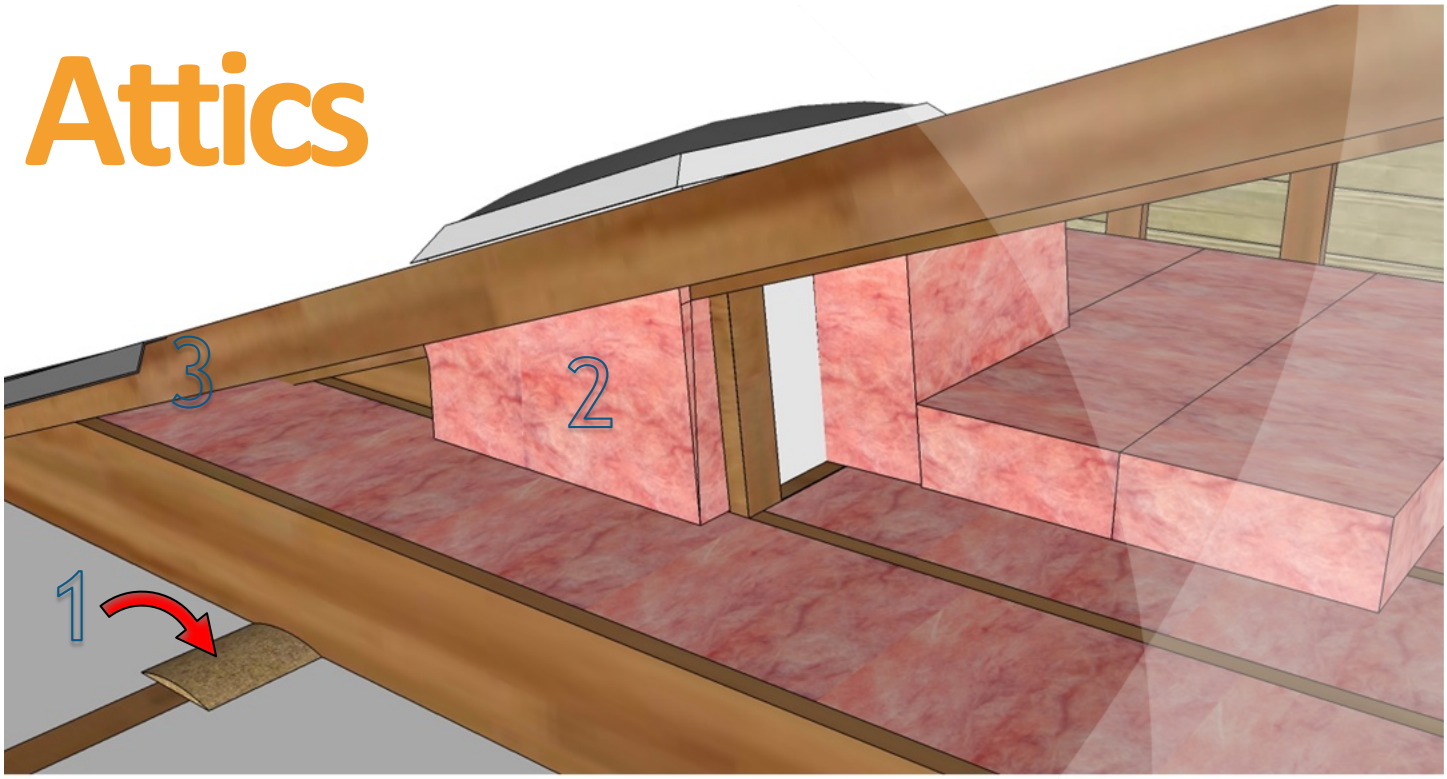
- People (if no one is inside, there's no Problem)
- Pollutant (chemical, particle, or microbial contaminant)
- Pathway (for the pollutant to travel to the people)
- Pressure (to move the pollutant along the pathway to get to the people)

The good news is that solving this Problem is simple: remove just one of the P's and the Problem stops. How exactly you do this is always more complex than it may seem, but at least the rules of the game are easy to understand.

VENTILATION TARGETS ARE NOT PERFECT- INSTALL A SYSTEM THAT CAN BE TURNED UP AND DOWN

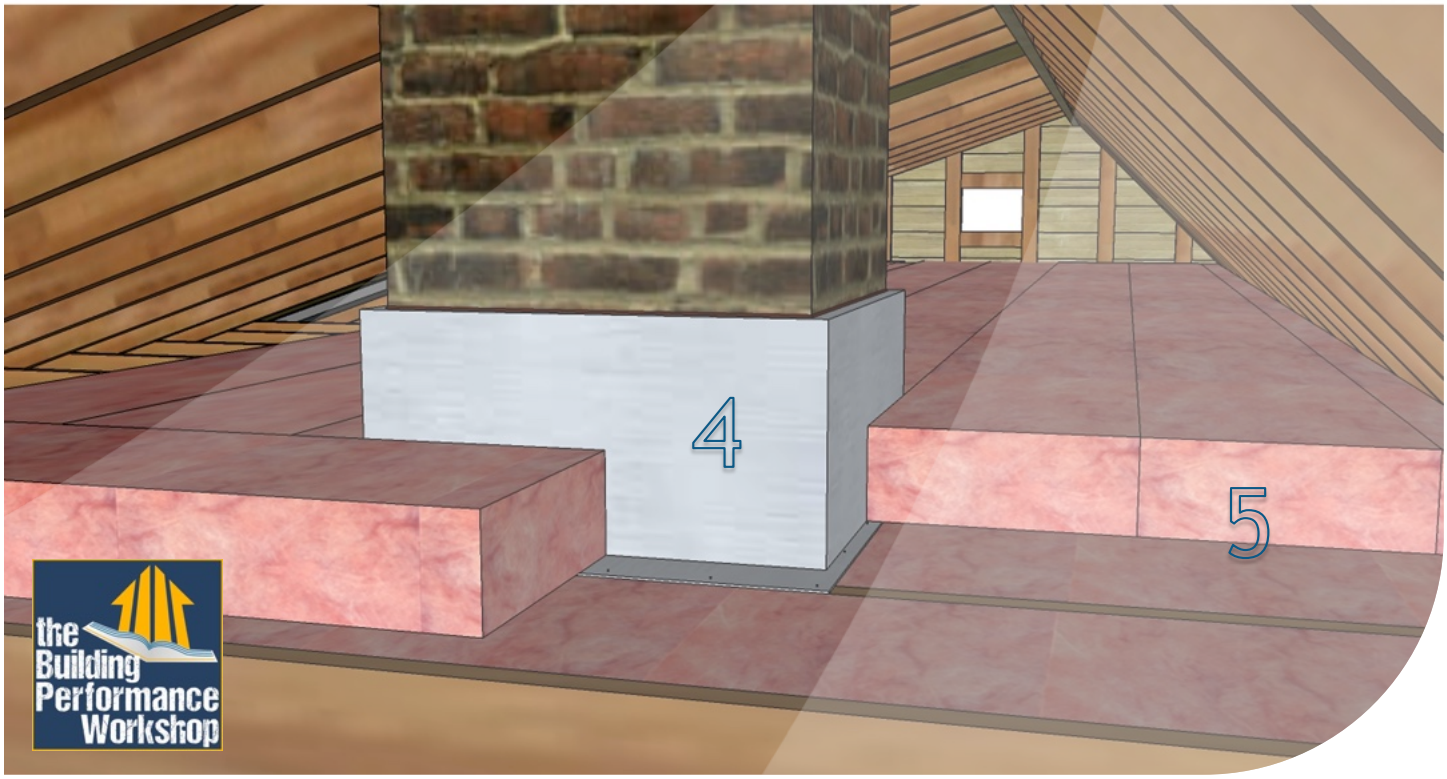
Solve Indoor Pollution Problems By Doing ONE: -Moving Out -Removing the Pollutant -Air Sealing -Installing Fans to Move Pollutant Away

Attics



And finally, take a look at how a home should be built.

- TOP PLATES of interior and exterior walls sealed airtight
- SKYLIGHT SHAFTS sealed airtight and insulated continuously and uniformly
- EAVE VENTILATION (if present) shielded with soffit baffles
- CHIMNEYS AND CHASES sealed airtight with a rigid material, fire-safe materials where needed
- ATTIC FLOOR insulated evenly and neatly, and deeply as feasible
- PENETRATIONS sealed airtight (electric wires, plumbing pipes, etc)
- RECESSED LIGHTS boxed airtight and insulated, where possible
- ATTIC AIR CONNECTEDNESS to home tested & proven to be <5% Zonal Pressure Proportion



The #1 mistake people make with attics and roof cavities is assuming that more insulation will make everything better. At best, more insulation does NOTHING if it's not undergirded by a quality air sealing layer, and at worst, more insulation can cause an increase in moisture problems (like mildew, mold, and rot) if it's not **airsealed first**. Because the attic or roof cavity is at the top of your home, it's where all the **heated air wants to escape** to in heating season, and where your **home breathes in** after the A/C has fallen out of holes in the bottom during cooling season. If your home uses more heating than cooling, you should generally improve the attic before any other part of the house.

BAD

GOOD

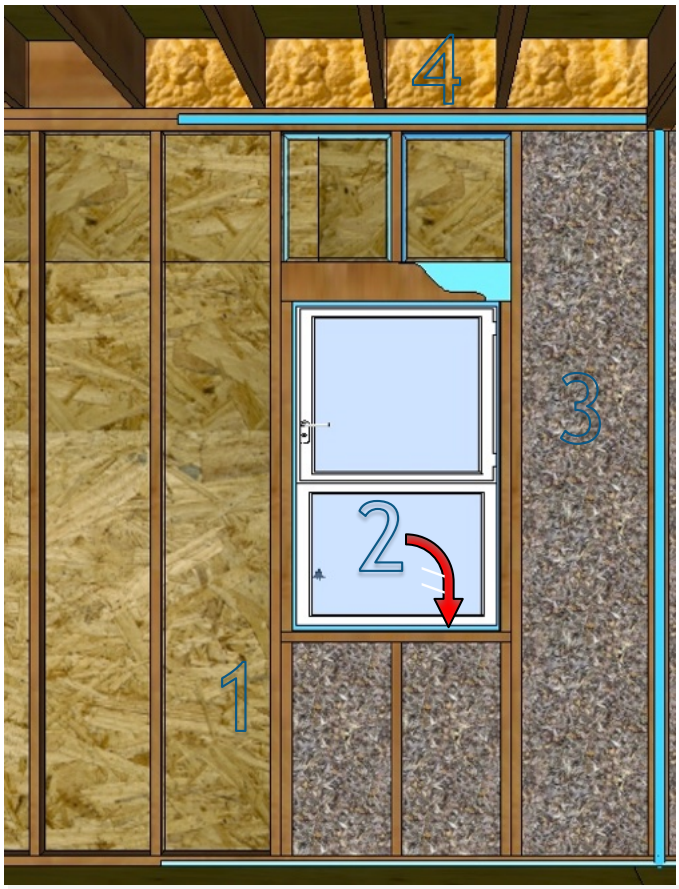
Side Attics

- FLOOR JOIST CAVITY blocked airtight at border of living space
- DUCTWORK sealed airtight & insulated to at least R-8 (more is better)
- KNEE WALLS sealed airtight at backside of drywall, insulated evenly & neatly, contained & sealed airtight w/ rigid foam insulation taped at seams
- ATTIC FLOOR insulated evenly and neatly, and deeply as possible
- EAVE VENTILATION shielded with soffit baffles
- ATTIC AIR CONNECTEDNESS to home tested & proven to be <5% Zonal Pressure Proportion

Often, you may not be aware your home even has these side attic 'mystery rooms', but if they're there, they're having an effect on your home's performance. The insulation may have been installed at the roofline, or at the wall and floor plane (or both), but the **airseal layer** will tell you whether these side attics should be INSIDE or OUTSIDE spaces. The wall between an attic and living space is called a **'knee wall'** because it's generally not a full-height wall. There are a surprising number of ways heat bleed can happen in a side attic: under the adjoining wall through the floor cavity, through outlets or insulation gaps in the knee wall, or even through wide open holes as you can see below.

BAD

GOOD



Walls

INSIDE SURFACE:

- The less framing, the better (more wood means less insulation)
- Sealant around windows, and at all joints
- Perfectly installed (RESNET Grade 1) insulation between studs (***air*** is the main insulating ingredient)
- Sealed and insulated band joist cavities (where the floor joists above meet the exterior wall)

EXTERIOR SURFACE:

- Cladding (siding, brick, stone... whatever covers the structure)
- Ventilation space (vertical strips that create a 1" space for water to dry)
- Drainage plane (waterproof barrier, in this case sealed building paper)
- Exterior insulation (taped at all seams for airtightness)
- Sheathing layer (plywood or similar, for stability)

Walls, like ceilings, provide structural support and **control layers**. The control layers are for controlling (you guessed it) **heat bleed, air leakage, moisture,** and **air quality**. Structurally, there are wood or metal studs, and in between these we put insulation. This is **not** the best way to control heat bleed- you should aim to add a **continuous layer** of insulation outside the structure (especially for metal studs, which bleed heat 400 times faster than wood). **Less studs** and **more insulation** is always the goal. No matter which type of insulation you use (they're all good, when used correctly), the main ingredient is **air**; any insulation that's crammed or squeezed has less air, and won't work correctly.

BAD

GOOD

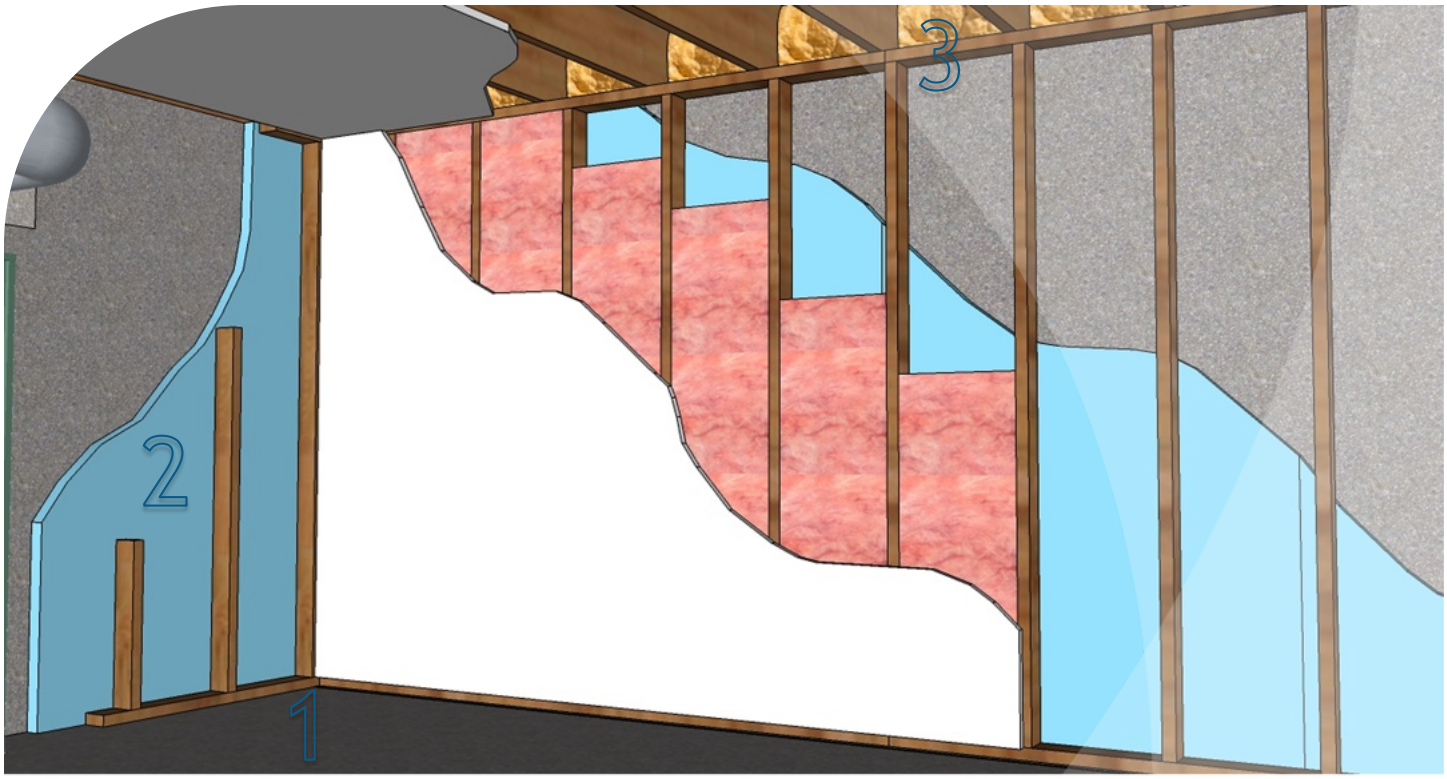
Garages

- CEILING JOIST CAVITY blocked airtight at border of living space
- KNEE WALLS sealed airtight front and back, and insulated uniformly
- WALLS TO LIVING SPACE sealed airtight front and back, and insulated uniformly
- ENTRY DOOR to home weatherstripped airtight
- DUCTWORK in garage ceiling/walls sealed airtight and insulated to at least R-8
- GARAGE AIR CONNECTEDNESS to home proven to be <5% Zonal Pressure Proportion

Garages must never be connected to your living space, since the stuff you keep in the garage (gasoline, paint thinner, cars exhausting carbon monoxide) are not healthy for your family to breathe. The main air connection between the garage and the house may not be the connecting door either, as there are tons of air pathways inside the **building cavities**, as you may already suspect. This is especially troublesome if you have a **'bonus room'**- a living space extending over the garage. Insanely, some building officials in that scenario will actually require holes to be cut in the ducts in the garage ceiling, which is a **huge hazard**. You can always discover these connections with testing.

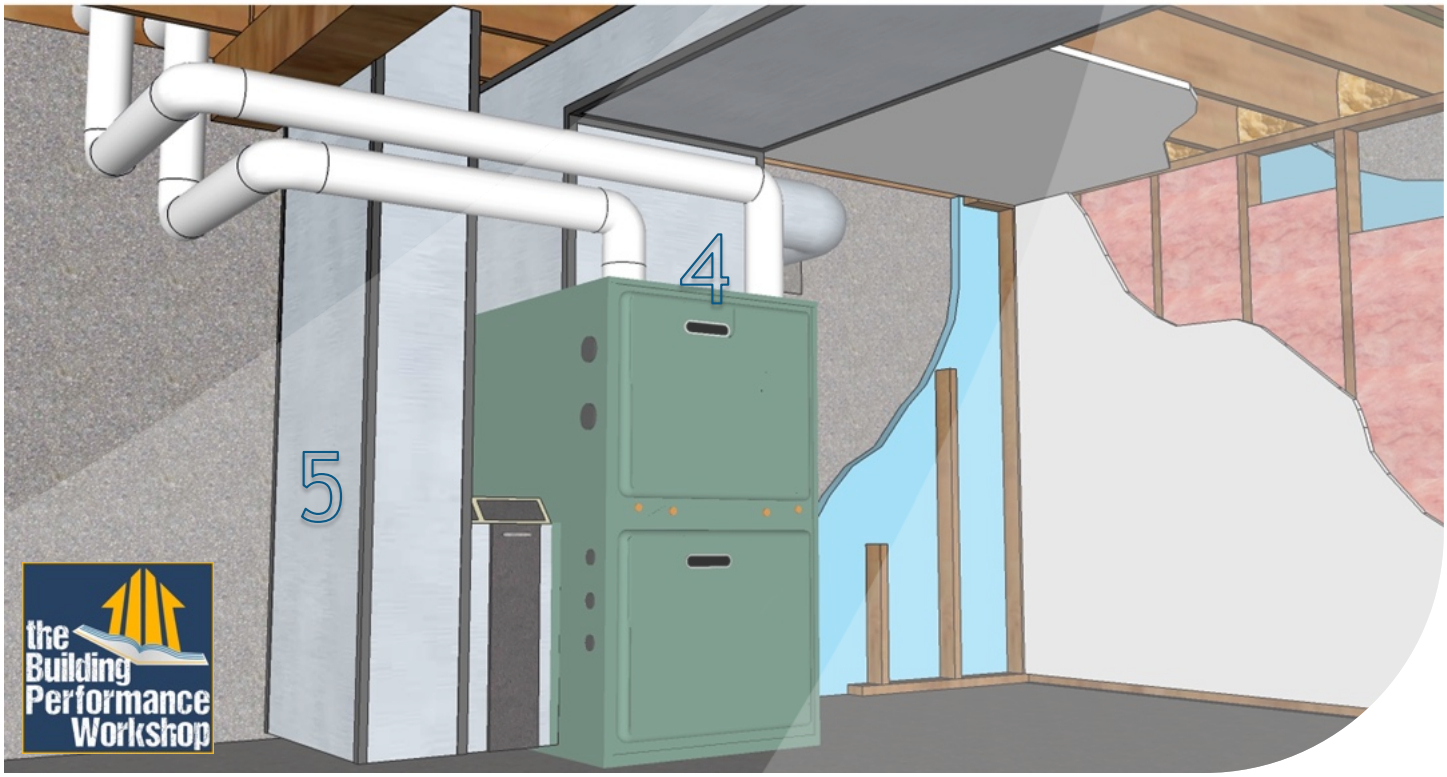
BAD

GOOD



Basements

- DRAINAGE managed with drain tile inside, outside, or both (w/ optional exhaust system)
- WALLS insulated continuously (NOT interrupted by wood framing) where possible
- RIM JOIST airsealed in all corners and insulated to the same level as the walls
- COMBUSTION EQUIPMENT sealed combustion with dual PVC piping
- DUCTWORK sealed airtight and insulated, FILTER SLOT fitted with airtight cover
- SUMP/EJECTOR PUMP sealed with airtight cover

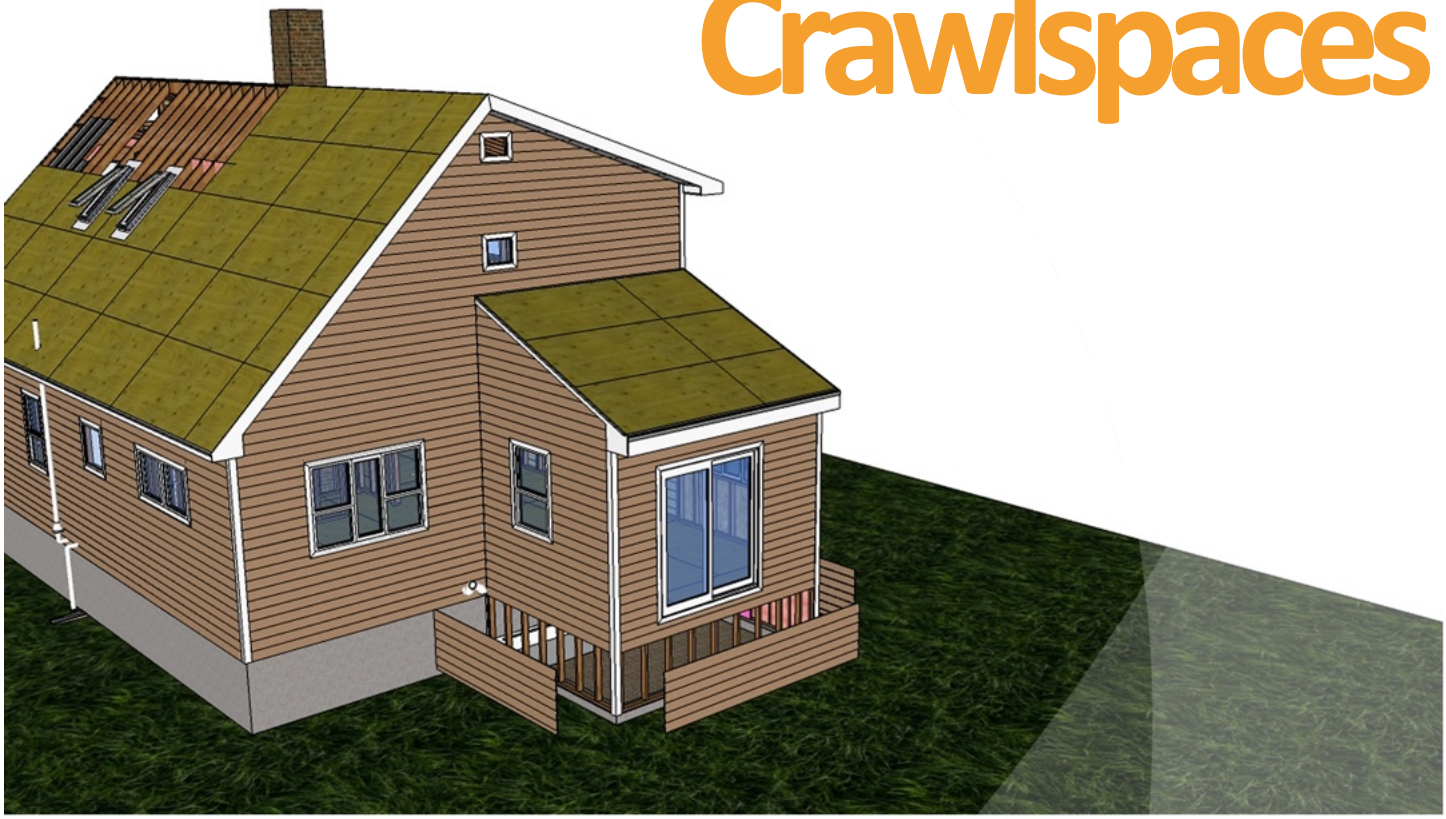


Basements can be complicated. They can get wet because of **groundwater** coming in or **condensation** of indoor humidity on cold surfaces. They get cold because they're in contact with the **underground** (55ºF year round), and at ground level they bleed heat too (if there's snow, that gets pretty cold). Air leakage can come through the **rim joist** (the perimeter of the floor joists overhead) or through cracks and pits in the **slab floor** (radon can be an issue here too). In 99.9% of cases, the basement is absolutely an inside space- the **insulation should be on the walls**, not in the ceiling. And **insulation for pipes and ducts** will keep heat from bleeding down through the concrete floor.

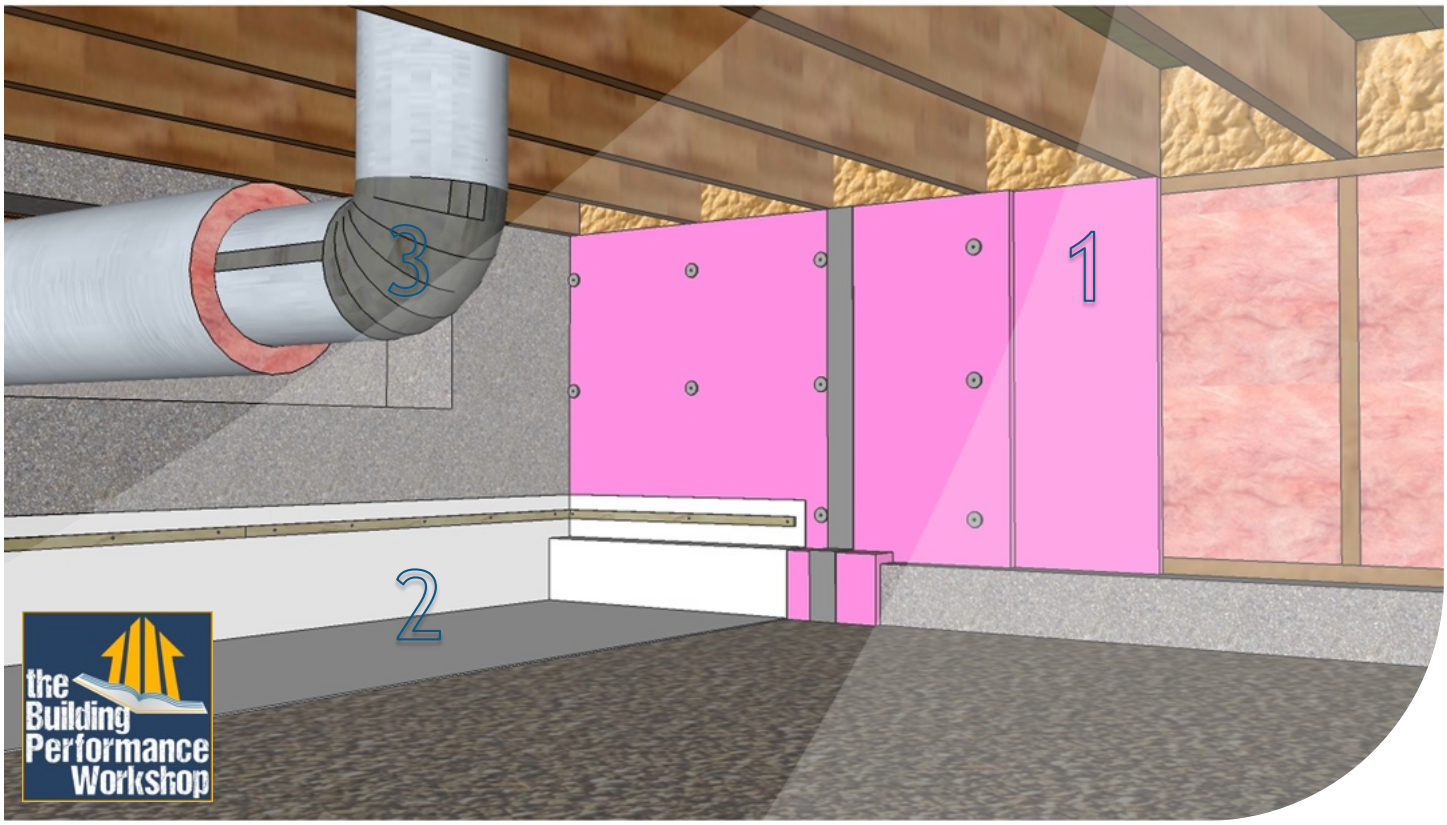
BAD

GOOD

Crawlspaces



- EXTERIOR WALLS and RIM JOIST sealed airtight, insulated evenly and neatly
- GROUND COVERED with >6mil plastic vapor barrier, sealed airtight at seams
- DUCTWORK sealed airtight and insulated to at least R-8 (more is better)
- CRAWLSPACE AIR CONNECTEDNESS to home proven to be >95% Zonal Pressure Proportion



Crawlspaces used to be vented to outside and considered outside space; testing has proven that approach causes a **lot of problems**. Plus, if you test any vented crawl with zonal pressures, you'd probably find that it's more airway-connected to the home than the master bedroom suite. Bringing a crawlspace fully inside is called **'encapsulation'**, and when complete, it should be the same temperature and humidity as the rest of the living space. The floor of the crawl is the only place in any house where a **sheet of plastic is always a good thing**. If you're pouring concrete, the plastic needs to go underneath. Insulation should generally go on the walls, and not in the ceiling overhead.

BAD

GOOD

Performance Testing is the simple process of finding out exactly what you're getting into, & checking that the effort paid off and everything actually works as planned at the end.

Performance Testing: the Ins and Outs

You must set **measurable goals** for your home. When you go out to eat at a restaurant, you have certain expectations: the food will be hot and taste good, not have any hairs in it, and be exactly what you ordered. Home improvements and new home construction are no different, except for the fact that most homeowners haven't been educated on **what our expectations should be**.

Your measurable goals should be guaranteed by your contractor based on **airtightness, temperature consistency**, **moisture/humidity**, **forced airflows**, and other **equipment performance** as compared to what the equipment says on the label.

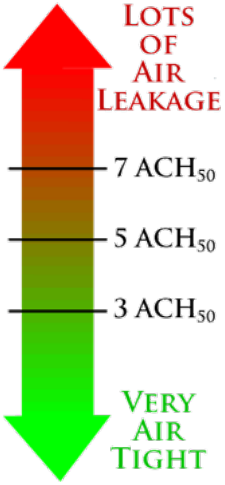
Don't let anyone tell you that it's 'unrealistic' to expect perfect control, or that it's 'too hard' to achieve. If you're looking for an example of perfect control delivered 100% of the time, look no further than the airplanes in which we all travel. As big as a house, they must be airtight, insulated, moisture controlled, and have excellent air quality, AND they are exposed to much greater pressures, winds, rains, temperature variance, and odor and contaminant problems than homes.

Nevertheless, if control is not perfect in an airplane, something catastrophic may happen. The jocular builders of airplanes are overall no different than the jocular builders of homes- they just understand the **consequences** of good and bad work, and they use checklists and testing to prove their work is effective. **Quality control** makes their work superior, and it's within our grasp in homes as well. You can see demonstrations of the following at *YouTube.com/HomePerformance*

Blower Door Testing

The enclosure should always be measurably airtight and insulated. Overall airtightness is tested by the **blower door**, which sucks air into/out of a home until standard pressure is reached (50 Pascals). Since we know how much air is flowing through the fan, we know how much is leaking through the gaps and cracks in the home's enclo

The blower door's reading will be in Cubic Feet per Minute (CFM) at 50 Pa, which can be divided by either the home's volume or enclosure surface area to show leakage in Air Changes per Hour (ACH50) or CFM per Square Foot of Surface Area (CFM/ft^2). You can also estimate the **cumulative size of the hole in the enclosure**.



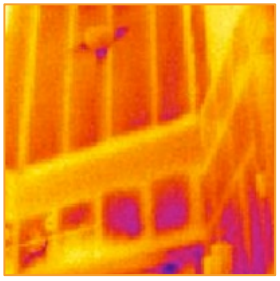
At present, ACH50 is more popular- 3 ACH50 is the leakiest allowable under International Energy Conservation Code (IECC) requirement- any builder can all easily aim for this goal. No code will likely ever require tighter as a minimum, so a home built to 3ACH50 today will meet code airtightness forever, theoretically.

REASONABLE TARGET: ***3 ACH50 or less*** *(for excellent control of comfort, humidity, pests, noise, and contaminants)*

Pinpointing Enclosure Issues

Zonal pressure testing is a critical part of locating the source of air leakage. While the house is under blower door pressure, we can see how much pressure relief happens in any room (or 'zone') when it's closed or opened to the house.

Every room of your home (including the attic, garage, and crawlspace) should be **either 100% inside or 100% outside** the enclosure based on its **Zonal Pressure Proportion** (ZPP). Anything in between shows an opportunity for improvement through pinpointed air sealing. If the attic shows a 60% ZPP before a much-needed airsealing of the attic floor plane, then the ZPP should be much closer to 100% after the improvement. If you airsealed and insulated between the attic and outdoors, it should have moved in the opposite direction- closer to 0% when completed.



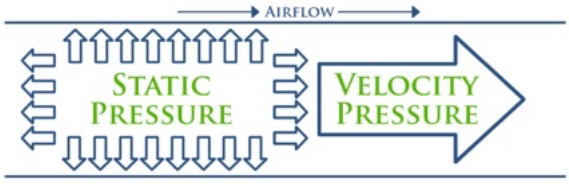
Infrared thermal photography is another excellent tool for visually locating areas of heat bleed because of missing/uneven insulation or air leakage. Because infrared is cool and sexy, you'll see this tool a lot. But be careful: pretty colors are dangerous. They can sell you anything.

In a photo like this one, **light colors mean warm** temperatures, and **dark means cold**- this color palette is called 'Iron', and it's generally the best for seeing heat bleed while also not getting confused. If you're trying to locate air leakage, **you need a blower door running**- otherwise, the infrared camera will miss most of the leakage that's happening (because of stack effect).

HVAC Testing

The HVAC's job is to move heat and air around, and it's possible to prove that the **correct amount of heat and air are delivered** with **airflow and temperature testing**, **pressure pan testing,** or **duct tightness testing**.

Your forced air furnace or A/C is like your body's circulatory system. The 'heart' of the system is the **air handler**, the fan that moves all the air. Like your own heart, it can be helped or hurt by the valves and arteries it's connected to, and it has a limited amount of power. It pushes against two types of pressure: **static pressure** and **velocity pressure**. There's only so much pressure to go around, and static pressure is stronger. The higher it is, the lower the velocity pressure, which means lower airflow. You want a low static pressure so that you can have a higher velocity pressure and get the right amount of air moving through the system as a whole.



At the supply registers, the air velocity (speed) should be fast enough to hit the air in the room like a bowling ball hitting the pins, which circulates the room's air pleasantly. This is between 500-700 feet per minute (fpm); any slower and the air won't circulate, any faster and you can hear the air whistling.

Exhaust fan testing is also essential: every bath extract should ideally be located over the shower and be exhausting at least 50 cubic feet per minute, your kitchen exhaust should be proven to empty outdoors, and the exhausts **shouldn't create major suction** inside the house for **carbon monoxide safety** reasons.

All fuel-burning appliances create carbon monoxide (CO) at least in small amounts.

Most CO detectors won't protect your family from low levels of this lethal odorless gas.

They're designed to totally ignore anything under 70 ppm, and they say that clearly in the manual.

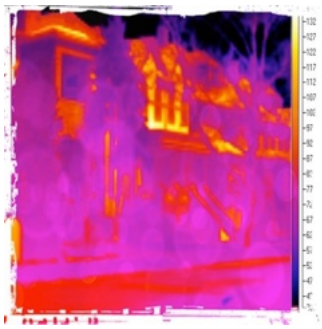
I wouldn't trust this thing to protect my family- would you?

There is no reason why you can't expect **guaranteed control** over a measurably comfortable, healthy, durable and energy efficient home. Stop wasting money, time and sweat on what doesn't provably work.
Stop guessing.

Proof Is Possible.
ask for it.

Air Tightness Testing

Build a plan for EXACTLY where and how much to air seal the Enclosure and Ductwork



Infrared Thermal Photography

See the Barriers to Heat Bleed with your own eyes

HVAC Testing

Ensure that temperatures and air flows are consistent & comfortable

Safety Testing for Side Effects

Prove that your home is tuned as a system, and that there aren't unintended consequences

NOW YOU CAN REALLY *OWN* YOUR HOME. NOTES!

Grace and Corbett Lunsford created the 3-season PBS series *Home Diagnosis* and publish the book *Home Performance Diagnostics: the Guide to Advanced Testing*. Their work tuning the invisible dynamics of home physics, chemistry, and microbiology led them to create hundreds of videos for YouTube's *Home Performance* channel, and to build the world's highest performance tiny house on wheels for the *Proof Is Possible Tour* to 34 cities in 2016. They now live in a self-built high performance forever home with 3 kids in Atlanta.

We'd love to get you the help you need, by either consulting or coaching with you over video, teaching you in self-paced courses, or connecting you with local pros.

Learn more or connect with us at:

BuildingPerformanceWorkshop.com
YouTube.com/HomePerformance
HomeDiagnosis.tv